The role of cortical interaction for spatial discrimination, localization and its learning-induced changes

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We provide a general computational framework to understand spatial discrimination and localization abilities and their alterations during learning. Cortical population activity is modeled using a mean field approach with a Mexican hat interaction of short-range excitation and longer-range inhibition. Single site stimulation evokes single peaks of activation, while simultaneous stimulation at two sites evokes 2 peaks. We assume that the former codes for the subjective experience of a single point, while bimodal distributions are read out for perceiving two. It has been shown experimentally that for large distances two peaks of activation interact only weakly, while lateral inhibition leads to substantial suppression for shorter separations [1].

Localization refers to the ability to precisely read out the location of monomodal distributions of population activation. Several approaches have been formalized how single parameters may be estimated from population distributions of activation (f. e. [4]). Psychophysically both long term [5] as well as short term plasticity [2] improve discrimination abilities on the cost of localization indicating a trade-off. Here we show that spatial discrimination and localization are affected oppositely by lateral interaction: While lateral inhibition leads to deterioration of discrimination it improves localization. This effect is due to a reduction of coexisting activation leading to smaller influences of noise and a subsequent reduction in the variance of the read out peak position.

Learning on a cortical level is assumed to be mediated through a decrease of inhibitory interaction. As a result, decreasing the strength of lateral inhibition in the model increases the size of the cortical representation as observed in fMRI studies [3]. For discrimination the decrease in inhibitory interaction leads to bimodal activation profiles for distances that before learning evoked single peaks explaining learning-induced improvement of discrimination ([2], [3]). In contrast, for localization weakening winner-takes-all mechanisms allows coexisting activation leading to stronger influence of noise thus deteriorating localization abilities. Combined, modeling lateral cortical interaction in population representations provides a unifying framework that explains task-specific requirements in tactile perception and their alterations evoked by perceptual learning.

References